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Agenda item 3 (e)

IMPLEMENTATION OF THE NAIROBI PROGRAMME OF ACTION FOR THE DEVELOPMENT AND UTILIZATION OF NEW AND RENEWABLE SOURCES OF ENERGY: CONTRIBUTION TO THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

Letter dated 7 February 1992 from the Permanent Representative of Norway to the United Nations addressed to the Secretary-General

I have the honour to request that the enclosed document entitled Hydropower - Utilization of Waterfall Energy in an Environmentally Sensitive World (see annex) be made an official document of the Committee on the Development and Utilization of New and Renewable Sources of Energy under agenda item 3 (e).

The report is the result of an international symposium held in Oslo, Norway, from 15 to 17 October 1991, as a contribution to the United Nations Solar Energy Group for Energy and Development (see A/AC.218/1992/2).

Energy use and efficiency are central issues in the efforts of the international community to reduce air pollution. In this context, hydropower merits closer attention as the most developed and - at present - most viable renewable power resource. As such, it should be included in an appropriate way in the Agenda 21, together with other renewable power resources.

(Signed) Martin HUSLID
Ambassador
Permanent Representative

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ANNEX

REPORT FROM A

SYMPOSIUM ON HYDROPOWER
its Potential and Environmental Properties in a Global Context *

Oslo, 15 - 17 October 1991

organised by

Norwegian Water Resources and Energy Administration (NVE)

on behalf of

Norwegian Ministry of Foreign Affairs
Norwegian Ministry of Petroleum and Energy
Norwegian Ministry of Environment
Norwegian Agency for International Development

and in collaboration with

The United Nations' Solar Energy Group for Environment and Development (UNSEGED)

A contribution to
the work for the United Nations' Conference on
Environment and Development in Brazil
June 1992

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* The annex is circulated in the langue of submission only.

HYDROPOWER

Utilization of Waterfall Energy in an Environmentally Sensitive World

Contribution to the United Nations Solar Energy Group for Energy and Development as preparatory work for the United Nations Conference on Environment and Development, Brazil 1992.

Report based on an International Symposium held in Oslo 15 - 17 October 1991, organised by the Norwegian Water Resources and Energy Administration on behalf of the Ministries of Foreign Affairs, Petroleum and Energy and Environment and of the Norwegian Agency for Development Cooperation

FOREWORD

This is the Report from a Symposium on Hydropower held in Oslo from 15 to 17 October 1991. The Report deals with the role of hydropower in the development of the energy sector under conditions of growing environmental sensitivity. It has benefitted greatly from the views expressed by a team of 40 experts in the energy and environmental fields which met in Oslo by invitation of the Government of Norway. It has been edited from the proceedings of the Symposium itself, and numerous written contributions made by the participants and others.

The participants in the Symposium were selected from all parts of the world,- developing and industrialised countries, representing different experience and background. The report could not be finalised at the symposium. therefore, the views expressed do not necessarily reflect in every respect the views of all participating experts.

The exercise consisted of preparatory work in the form of a draft report, a three day symposium and the drafting of this final Report. The primary purpose of this exercise has been to contribute to the work of the United Nations Solar Energy Group for Environment and Development (UNSEGED) by preparing basic information for the United Nations Conference on Environment and Development (UNCED) in Brazil in 1992.

A secondary purpose, of course, is to provide decision-makers and participants in negotiations of international agreements, with information on the potential role of hydropower in Sustainable Development.

The Norwegian Water Resources and Energy Administration was asked to arrange the Symposium. The work programme was discussed and clarified with the relevant Ministries in Norway and with professor Thomas B. Johansson, Chairman of the UNSEGED.

The picture is by no means a simple one. Hydropower is a well established, renewable source of energy with great untapped potential. It has also its drawbacks, as the Symposium stressed. Protagonists for several different viewpoints and from all corners of the world were gathered at the Symposium. We therefore trust that this Report gives a balanced account of the discussion and that we have been able to give a fair and balanced view of the role which waterfall energy plays as a constantly regenerating and non-polluting source of energy for present and future generations.

The work has benefitted from financial support by the Government of Norway and partly by the countries and institutions from which participants were invited to the Symposium. We are grateful to all the contributors for the help they have given.

The participants in the preparatory work of this report represent an outstanding world wide expertise on hydropower seen from all viewpoints. Every one of them showed great interest in the work undertaken and gave valuable contributions to the drafting of this report.

Thanks go also to members of the Advisory group,- for their enthusiasm and strong engagement. This goes also to Michael Fergus, the appointed rapporteur, for pleasant collaboration during the whole process. Last but not least I want to thank Lisbeth Karijord and Grethe Mathiesen for their help in organising the symposium and getting the report ready.

Being a country where all electricity is supplied in the form of hydropower, Norway was pleased to host this Symposium and make this contribution for the preparation of the UNCED 1992.

Asbjørn Vinjar
Symposium Director

Oslo, November 1991

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HYDROPOWER - UTILISATION OF WATERFALL ENERGY IN AN ENVIRONMENTALLY SENSITIVE WORLD - REPORT OF A SYMPOSIUM

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0. THE FINDINGS OF THE SYMPOSIUM

Findings

A major function of the Symposium was to advise the United Nations Solar Energy Group for Environment and Development (UNSEGED) who were holding their final session at the same time in Oslo. It was to advise on major issues concerning the role of Hydropower for development of energy supply in a world with growing concern over the Environment.

The following are the Symposium's principal findings which were communicated to UNSEGED at the conclusion of the Symposium.

1. Hydro-power is the only renewable energy source derived from solar radiation of any consequence for power supply at the present time. It is a mature technology where the positive and negative impacts are well explored. At present hydropower is the most important commercially available renewable technology. Correctly developed it fits well the label "sustainable development".

2. Through the natural solar driven cycle of water from the sea to falling rain and snow, Nature provides in waterfalls concentrations of energy which are relatively easy to enhance by engineering measures.

3. The amount of hydro energy currently considered to be technically exploitable is estimated at 12,000 TWh of which only 17% i.e. 2,100 TWh have been exploited to date. Currently hydropower constitutes 18%, thermal 64%, nuclear 17% and geothermal 0.5% of electricity produced from all sources. Developing countries have the major part of the remaining potential in the world and less than 10% of the technically exploitable potential is developed. It is, however, recognised that environmental and socio-economic factors related to the site-specific nature of hydropower can reduce such potentials considerably. The amount of exploitable potential of hydropower is not fully investigated in all developing countries.

4. Hydropower can be developed in a flexible manner to meet varying demands and changing conditions. Depending on the site, hydropower plants can be built to any size, from the very smallest to more than ten thousand megawatts. As a renewable source of energy, hydropower represents by far the largest contribution to the supply of electrical energy.

5. Hydropower schemes can be successfully developed in the context of multipurpose use of water.

6. Hydropower developments carry with them the potential of being environmental eyesores and causes of social upheaval. However, the converse of this is that energy is generated virtually without adding to pollution of the biosphere and to global warming. In addition planners have learned to minimise the negative impacts by the environmental assessment procedures adopted. They have also learned to accept reduced project scale or project abandonment as legitimate planning alternatives.

7. It is essential to identify the total costs and the total benefits arising for a particular hydropower source. The total cost includes development and construction expenses, environmental and socio-economic costs as well as running costs. Countries with potential hydropower sites should establish hydropower development policies including assessment of costs, benefits and environmental degradation and a legal framework for implementation of policies adopted. They should also establish organisational structures to handle the establishment and operation of plants as well as authorities charged with seeing that necessary environmental and economic measures are taken.

8. Because hydropower is largely site-specific it must be developed in accordance with natural characteristics. Hydropower development of major river basins makes it essential that there should be regional co-operation. Large-scale hydropower, which can cause environmental damage to an area, can also bring large benefits to an extended supply area. Unit costs may be lower than for small-scale developments, and environmental degradation may be less if seen in a broader geographical context. Concentration of development impacts may, in some cases be preferable to smaller-scale, more dispersed development.

9. It is essential for water resource management and hydropower development to have continuous monitoring of hydrometeorological data. An effort must be made to make appropriate resources available for this purpose.

10. In connection with the Global Warming issue hydropower planning should include assessment of the project's net impact on the country's Carbon Budget, considering displacement of alternative generation modes, deforestation and loss of carbon fixing land areas.

11. Changing public awareness goes in favour of hydropower compared to fossil fuels, provided the environmental merits are taken into account. The high initial capital requirement can be eased by judicious staging of the development. When comparing different and alternative projects in decision making one should take full account of the long asset life and the substitution for alternative polluting power sources which hydropower offers.

Conclusions

WHEREAS: Hydropower is:

- "Clean" i.e. non-polluting and a net mitigator of global warming
- The most important renewable source of energy so far
- A mature technology
- Relatively simple and cheap to operate and with low maintenance costs
- Long-lived because of the predominance civil works
- Appropriate for local participation because of the civil works component

ADMITTING THAT:

Hydropower may impact the Environment in the form of:

- Inundation of land areas by reservoirs
- Displacement of populations
- Water-borne diseases in tropical areas
- Changes of natural waterflows which influence aquatic life in regulated rivers
- Local climate change
- Threat to recreational values of river systems
- Socio-economic changes of the locality concerned

REALISING THAT:

Energy for sustainable development should be based on the following principles:

- Maximising efficiency in energy use
- Substitution of renewable for non-renewable sources of energy
- Curbing of greenhouse gas emissions
- Securing local participation and livelihood

and further

- The potential for multi-purpose development of water resource including conservation can be more seriously considered than hitherto

- Financing of hydropower plants does not normally reflect the sustainability of hydropower compared with other generating forms

- Hydropower's longevity is not properly reflected in conventional Hydropower appraisal methods

The following CONCLUSIONS can be drawn from the hearings and discussions:

- That hydropower be considered the most interesting, and by scale, the most

important renewable source of energy for meeting power supply needs

- That benefits and costs must be evaluated and balanced as a basis for decision

- That the establishment of proper hydrological data is essential

- That national and international guidelines for the development of hydropower should be formulated

- That national legal frameworks and international compensation guidelines need to be developed

- That appropriate organisational structures have to be developed to ensure the legal framework is adhered to

- That hydropower should be viewed as a major instrument in addressing global environment problems when the potential of energy conservation is exhausted.

The following ACTION is proposed:

National level:

- Each country should establish hydrometeorological data collection covering as many years as possible in diverse river systems and see to it that this activity is properly organized and funded.

- Each country should establish and keep up-to-date an inventory of its exploitable hydropower potential.

- Each country should keep up-to-date an energy plan covering supply and use in which the role of hydropower as a renewable source of energy should be included.

- Each country should revise its legal framework to take full account of renewable sources of energy including hydropower as a mean to maintain the balance between energy needs and supply.

- Each country should see to it that the organizational structure,- governmental as well as regulatory and energy supply units-, are fit for development of hydropower and for collaboration and co-operation with other water users.

Energy sector:

- The energy sector should be encouraged and urged to favour technologies which do not lead to degradation of the environment and in this regard take due account of hydropower as the most reliable and important renewable source of energy so far in use around the world.

- On regional levels power suppliers in neighbour countries should collaborate to maximise the benefits of interconnecting hydropower systems and thermal power

systems.

- Where huge hydropower potentials exist in large rivers without adequate power demand regional collaboration for the supply of extended areas, if necessary covering two or more countries, should be encouraged.

Local level:

- Regarding public acceptance in developing hydropower sites, it is recommended that the local population affected by the project and other parties having a legitimate interest in the project are brought into the planning process which forms the basis for decisions,- whether or not the project shall be implemented, to which degree and on what conditions.

- It should be considered how and in which way the local community should benefit from a hydropower project. Small scale projects for rural electrification give benefits to the rural community. Large scale hydropower projects should in a similar way accrue long term benefits to the community most affected by its implementation.

Clean versus polluting technologies:

- Renewable sources of energy should be developed to reduce emissions resulting from the use of hydrocarbons. This will not take place unless incentives are given to encourage decision makers to choose clean instead of polluting technologies. This will have to be reflected in national policies and legal frameworks. Incentives may be in the form of regulatory measures, such as taxes, levies, subsidies and tradeable emission permits.

- Full accounting of all costs of alternative forms of energy should help reduce concern regarding higher initial capital costs of hydropower.

- Concerns with regard to high initial capital requirements of hydropower could be eased by multipurpose project formulation with corresponding increased funding by other functions, and by staged construction of capacity commensurate with demand.

- Adoption of universal environmental criteria should tend to encourage international cooperation and funding, both through increased direct international loans and grants, and increased governmental support for investment by private concerns.

- Capital expenditures must be discounted by using a real rate of return and future benefits should not be undervalued or investments skewed to the short term or returns to capital distorted.

- International agreement should be reached on maximum permissible global emission of pollutants and how these should be shared between the nations. It should also include agreement on mechanisms on how emission permits in one country could be subject to international trading on the condition that the proveny from the sale of permits can only be reinvested in support of non-polluting technologies. The United Nations Conference on Environment and Development, Brazil 1992 is

encouraged to arrive at such agreement and to use hydropower as an example of a non-polluting technology.

Knowhow development:

- Need to assure continuity by developing a series of projects which justify the establishment of the institutional framework for development of hydro projects and the training of local individuals.

- Need to establish the responsibility for decision making by local individuals within the institutional framework.

- Start with individuals at a basic level; for example start with plant operators and train them in the aspects of hydropower; as they gain experience, progressively move them into positions of decision making.

- Start with small-scale projects that use simple construction to involve local mechanical workshops for maintenance.

1. INTRODUCTION

1.1 Objective

The Report is intended to present a review of the contribution that hydropower can make to the benign exploitation of renewable energy resources. It is to form part of the contribution to the work of the United Nations Solar Energy Group for Environment and Development (UNSEGED). This Group, under the chairmanship of Professor Thomas B. Johansson of Sweden, was to submit their Report in turn to the United Nations Committee on New and Renewable Sources of Energy (NRSE) on January 6, 1992, as their input to the United Nations Conference on Environment and Development (UNCED) in Brazil in June 1992.

1.2 Work Plan

A Draft Report on "Hydropower in a Global Context" was prepared by a five member group of Norwegian experts with extensive experience in hydropower. This Report was made available to the team of experts prior to their arrival in Norway and their comments and suggestions were invited. Written material prepared by the team members was distributed before the meeting and a document base for further discussion was thus set up.

At an initial plenary meeting, the objectives of the exercise were outlined and the proposed approach reviewed. The team was then split into sections, each to deal with the principal topics under discussion. The views of each section were summarised in brief notes.

Two work groups were then formed to review all the summary notes in two parallel sessions, a rapporteur in each group preparing notes on the discussion that ensued and on the principal findings. A summary of this material was presented to a final plenary meeting of all experts.

The discussion at the Symposium also formed the basis for comments on the Draft Final Report of UNSEGED and submitted to its Chairman for consideration before the final meeting in Oslo on October 17 - 18, 1991. This was held immediately after the conclusion of the Symposium.

The present Report is based on the material thus assembled, viz.

- the original Draft Report
- comments and submissions from members of the expert team
- section notes on a number of selected topics
- notes from the rapporteurs of the two work groups
- incidental observations submitted by participants during and after the meeting.

The Report presented herein is a synthesis of all these inputs and was finalised by the Symposium Rapporteur and the Symposium Organiser in consultation with members of the Advisory Group and others who participated in the Symposium.

1.3 Guidelines Set

Hydropower is to be considered as one of a number of options for supplying electricity to an identified power market. Exploration and analysis of this market is not to form part of this exercise; and, although recognised as vital, questions of electricity supply management and conservation are to be left out of account. Discussion is to concentrate on issues that place hydropower in its proper context, positive as well as negative. The renewable nature of the resource and its non-polluting properties are to be kept in mind, while the focus is on environmental and socio-economic impacts and enhancement opportunities.

The properties of hydropower compared to other sources of energy have not been subject for discussion or evaluation during this work. However, some general views are expressed regarding hydropower's actual and future role in electricity supply.

Most of the remaining hydropower potential not yet developed exists in a number of developing countries. Although it is appreciated that such countries deserve primary consideration it was decided to deal with the role of hydropower in a global context with emphasis on the growing environmental sensitivity in the industrialised world as well.

The material given in the present Report is intended to conform broadly with these guidelines.

2. ENERGY AND SUSTAINABLE DEVELOPMENT

2.1 Options for a Sustainable Development Policy

The trade-off between Environment and Development has become increasingly important in recent years. It has also become apparent that Man, in his exploitation of the Earth's resources, has been coming up against certain limits to growth. A high level of productivity is needed to maintain the current standard of living of the worlds population and improvements in material prosperity for the poorest are also needed to secure basic needs and to slow population growth. Energy is needed to produce and transport food as well as to process the raw materials of industry. With depleting resources and the threat of global climate change, the need for a sustainable development policy is therefore overriding.

Any discussion of hydro-power's role in sustainable development must take account of the findings of the UN Commission Report on Environment and Development. The Report states that sustainable development should "..... meet the needs of the present without compromising the ability of future generations to meet their own needs". (ref 1 Annex 2). A strategy for sustainable development requires a political system where all citizens may participate in the decision-making process, an economic system which can operate on a sustainable basis, a social system which can resolve conflicts harmoniously, a system of production which takes account of the ecological basis for development, a technological system which continually provides new ideas, an international system which promotes a sustainable basis for trade and financial dealings and a flexible administrative system capable of self-criticism. This may seem Utopian, but it represents the basis for assessing all energy technologies from a sustainable development point-of-view.

2.2 Global Climate Issues

Until recently the concept of "sustainability" as applied to different energy forms had been confined to the physical limits imposed by known resources e.g. 2,500 years with coal, 100 years with oil etc, or by the limits imposed by the physical environment e.g. conflicts between different land-uses. In recent years there has been a growing awareness of and concern over the long-term impacts on global climate of different energy technologies.

There is, however, also great uncertainty concerning such impacts, and how these can best be tackled. It is generally accepted that the amount of Carbon Dioxide and other "greenhouse gases" in the Earth's atmosphere are increasing and that these are likely to contribute to a general warming of the atmosphere through the "Greenhouse Effect". Carbon dioxide contributes about 50% of this increase due to human activity and arises principally from the burning of fossil fuels and decay of organic materials. The estimated global warming effect of fossil fuels is a major issue in a sustainable energy policy. It can also be a source of contention between rich and poor countries. It has been forcibly argued that developed countries --- as the principal emitters of greenhouse gases --- should make financial assistance available to developing countries to enable them to reduce production of such gases. The

Global Environment Facility (GEF) is a first step in that direction. The imposition of a so-called "Carbon Tax" is another. It has been estimated that about 25% of to-day's Carbon Dioxide emissions from human sources originate in the United States. Some countries have been calling for the introduction of a system of Tradeable Emissions whereby countries can co-operate to solve joint emissions problems. (Ref. 2 Annex 2)

It has to be pointed out that hydropower will add to the global warming effect when reservoirs are cleared in forested areas or when rotting vegetation accelerates the eutrophication processes on inundated land. However this is most unlikely to be very significant except for large water bodies in tropical forests. Research is needed to clarify these questions and should be observed by future hydropower planners.

The global warming potential of different energy forms will therefore have a very significant effect upon their long-term sustainability. The principal alternatives to fossil fuels are biomass, nuclear and hydro-power, with photo-voltaics and perhaps wind-power emerging on the scene. Although nuclear energy emits no greenhouse gases it is still considered problematic because of lack of public trust, the possibility of serious accidents, the difficulties in handling wastes and the dangers of nuclear weapons proliferation. It has to be borne in mind, however, that in some countries a large share of energy comes from nuclear sources; in France over 60% and in Sweden and Belgium, sizeable proportions.

At its recent meeting in Oslo, the Nordic Council Parliamentary Conference on "Energy for Europe", with participants from many European countries underlined the need to: " ..... pursue a higher degree of independence from imported oil .... and a reduction of the emissions causing changes in the global climate and limiting the quantities and further spread of plutonium ...." (Ref. 3 Annex 2).

2.3 Towards an Energy Policy for Sustainable Development

The following are suggested as the main components of an energy policy which will promote sustainable development:

- It should maximise efficiency of energy use
- It should substitute renewable for non-renewable sources of energy
- It should curb greenhouse gas emissions
- It should secure local participation and livelihoods

With these constraints the potential of hydropower can be addressed.

There is little doubt that, on a world-wide basis, demand for commercial energy will at least double in the next 15 years. The Brundtland Commission Report argues strongly that improved energy efficiency will be a major contributor to meeting this demand. This is particularly so in developing countries where the lack of cash hinders the use of energy efficient fuels. The Commission therefore sees a "low energy path" as the one to follow in the future in order to achieve sustainable development.

Even more important, however, than energy efficiency is the development of Renewable Sources of Energy (RSE). The switch from an energy-intensive world to a low energy consumption world will give time to develop RSE. Some of these sources e.g. hydropower are already well established and developed. This should be the basis for long-term global energy policy and strategy while improved energy efficiency will be the basis for the short- and medium-term.

The pressing need to reduce the emission of greenhouse gases is one which puts considerable onus on coal, diesel, petroleum and natural gas. It has virtually no impact on solar and nuclear power technologies including hydro-power.

There is greater need for local democracy and local participation in decision-making on energy issues. There is general agreement on the need for greater decentralisation of decision-making, and this is likely to be promoted through the development of Renewable Sources of Energy. There is a particular need to relate energy development to the securing of local livelihoods so that site-specific energy development also implies economic development for local people.

3. HYDROPOWER - AN OVERVIEW

3.1 General Characteristics

Mechanical energy from falling water has been made use of for centuries. With the advent of the production of electricity by rotating electro-magnetic machinery some 100 years ago, it was realised that this energy could be readily converted to electric power; some of the oldest generating plants ever built were based on waterfall energy. This energy is still an important source for the supply of electricity.

Waterfall energy, depends on solar radiation and can be considered as a particular type of solar energy. It is a clean and renewable energy source and creates no atmospheric pollution. Its unique environmental characteristics have come much into focus in view of recent concerns over threats of climate change caused by burning fossil fuels. It is estimated that, if all hydropower plants in the World were replaced by fossilfuelled plants, the total amount of carbon dioxide due to human activity would increase by 10%.

Hydropower represents a mature technology with low and stable operating costs. The conversion efficiency from the primary waterfall energy to electricity lies in a range of 85 - 90%. Other advantages with respect to fossil-fuelled plants are the long asset life, ease of operational control, rapid response to fluctuating demands and virtually loss-free output regulation. Hydro plant storage reservoirs offer at present the major form of stored energy which can rapidly be converted to electricity.

Hydropower production can be readily combined with other uses of water for irrigation and water supply and they can also be integrated into schemes for flood control and even canal operations. A number of such multi-purpose schemes have been built. The demand for water is expected to grow considerably in the future and the association of hydropower in a multi-purpose context is likely to become more prominent.

There are also substantial disadvantages associated with hydropower schemes, especially the larger projects that have been built on main rivers. The storage of water has led to harmful effects, particularly under tropical conditions. Changes in the flow regimes of rivers have led to erosion and undesirable silt retention and both amenity and livelihood have been affected by the impact of large-scale development. Criticism has been levelled against the damage to the ambient ecology that can arise from interference with the natural environment; such criticism is not only directed at hydropower but also at multi-purpose schemes which impound and abstract water.

Hydro schemes require a large front-end investment, as indeed do all major civil engineering works. Although subsequent operating costs are very low, the initial capital outlay can lead to financing problems. On the other hand, the lifetime costs per unit of electricity produced, are generally lower than those of alternative means for power generation and this is indeed one of the major merits of hydropower.

Hydro schemes are strictly site-dependent and are therefore often sited remotely from the load centres which they supply. Access roads and the necessary transmission lines increase investment requirements and environmental impact. As for the schemes themselves, much can be done to offset negative impacts arising from hydropower development through improvements in design and technology, and through careful attention to operating conditions. These matters are discussed further in this Report.

3.2 Resource Exploitation

The technically and economically exploitable hydro potential in the world is estimated to be 12,600 TWh annual producibility. In practice, the figure may be considerably smaller because of environmental and socio-economic constraints. However, it may also be that the estimate of the total potential is too low due to the fact that there still remain potential hydropower sites in some developing countries which are not fully explored. Some 2094 TWh, or 16.6% of the exploitable registered potential, have been developed in 1989. Exploitation has been greatest in Europe (62.8%) and North America (72.9%) and least in Africa (4.1%) and the USSR (7.0%). Both Asia (10.87%) and South America (11.4%) still have a large potential available and, in view of their large populations, it is likely that exploitation of their hydro resources will be substantial in the next few decades.

The developing countries have 59% of the world's exploitable hydro capacity; six countries account for 60% of that figure (Brazil, China, Colombia, India, Indonesia and Turkey). Estimates are distorted to some extent by the uncertain potential of some of the large river basins in Asia, in particular the Mekong River; this alone is thought to have a potential of 300 TWh of which only 0.5% are used at present.

The most recent statistics for some of the major hydropower countries are shown in table 1.

Table 1: HYDROPOWER POTENTIAL IN SOME COUNTRIES
1989

	Exploitable TWh/year	Produced TWh/year	% of exploitable	% of power generation
Angola	100	1.3	1.3	72.2
Austria	54	36.1	66.9	71.9
Brazil	752	213.4	28.4	92.9
China	1923	118.5	6.2	20.4
France	72	69.6	96.7	17.1
Indonesia	709	8.6	1.2	20.5
Madagascar	120	0.3	0.3	50.0
Norway	172[1)]	118.7	69.0	99.9
Switzerland	41	30.5	74.4	56.7
USSR	3220	224.0	7.0	13.0

[1)] Of which 125 TWh is so far set by the Storting (Parliament) as a maximum target.

Source: See Ref. 4 Annex 2

The world total for the share of hydropower in the electricity generation from all sources amounted to 18.3% in 1989. In 1989 installed capacity in hydropower stations amounted to 567 gigawatts (GW); 110 GW was under construction. Pumped-storage capacity was 89 GW, of which 67% was in Europe.

The exploitation of hydro resources does not depend solely on the availability of the resource. It also depends on the disposition of this resource with respect to the demand centres and on the availability and cost of alternative sources. In many parts of the world, traditional fuels such as firewood and biomass are cheap and readily accessible although their use is inefficient, polluting and environmentally damaging. Some countries have vast resources of fossil fuels which are conveniently located and tend to take precedence over hydropower, in spite of the emission problem they create.

3.3 Future Scope

Various scenarios have been developed for the future growth of energy demand as a whole and of the allocation of this demand to the different energy sources. The most recent estimates produced by the World Energy Council suggest that the world population will continue to grow at an annual rate of 1.6% up to the end of this century but that the growth rate will then decline to about 1.4% for the first quarter of the next century. The growth rate in the developing countries is expected to be some 3 to 4 times greater than in the industrialised countries. With moderate growth of the world economy, the rate of growth of the energy demand as a whole is thought to remain slightly ahead of the population growth and fall from an initial rate of 2% per annum to 1.6% by 2025. The growth rate in the developing countries would be about twice that in the industrialised countries. Even if only a low rate of economic growth is achieved, the rate of increase of the energy demand is not expected to fall far behind the population growth. These figures suggest that the main effort in development and investment will be in the developing countries; indeed it will have to be in these countries if economic stability is to be maintained.

Expectations are that the role of hydropower will not greatly change in the foreseeable future. Currently, some 6% of the primary energy supply are contributed by hydropower. The fear of excessive atmospheric pollution is likely to accelerate hydropower development but the effect is not thought to be dramatic at least on present estimates according to which 7.3 - 7.7% of primary energy will come from hydropower by 2025. This percentage will not be significantly affected by the rate of economic growth. It implies that hydropower production will have to double between 1991 and 2025.

The supply of hydropower far exceeds that from all other commercial forms of New and Renewable Sources of Energy (NRSE). The share of hydropower in the total amount of electricity produced in 1989/90 was 18.3% as compared with 1.1% from other sources of commercial Renewable Sources of Energy (RSE). The amount of energy derived from non-commercial forms of RSE is however substantially greater, that from biomass being about twice the amount of hydro energy. The development of commercial NRSE is likely to accelerate considerably over the next decades, but hydropower has the potential to be the largest source of RSE well into the 21st Century.

The question remains which role hydropower will play. It will depend on what incentives will be given to the development of this source of energy on local, national, regional and international levels and on the decisions made in each country having access to hydropower sites inside or outside their borders.

A recent survey "Energy for a Sustainable World", see Ref. 7 Annex 2, demonstrates the need for an increase in electrical energy in the developing countries from 110,000 MW in 1980 to 565,000 MW in 2020. Assuming, on average, a continuing role of hydro at about 20% of total, the hydro component would be some 90 GW. This figure is speculative but it indicates that further development of hydropower will be of significant magnitude.

3.4 The Importance of Hydrological Data

The temporal and spatial variation of natural flow in rivers is a basic factor in the planning of hydropower and power systems as it also is for other uses of water.

The significance of adequate hydrological data cannot be over-emphasised. Accurate and systematic observations of river discharges over several decades are required. Precipitation measurements alone cannot give a true measure of run-off in a river basin. Information on evaporation, accumulation of snow and ice and soil and groundwater characteristics also contribute to more reliable data.

Systematic data collection combined with the use of computer models are therefore features of the hydrometeorological system necessary for adequate hydropower development. Experience indicates that hydrological and meteorological services should be combined where possible. Financially losses arising from inadequate hydrological data are not readily available. However, in some cases these must be very substantial in terms of over- or underdesign of schemes.

In many developing countries the organization of hydrological services is ignored or given a low priority. This is because the importance of these services is not recognized. As a result, hydrological data collection is often highly inadequate for the proper planning and design of a hydropower project.

Countries with hydropower potentials should allocate financial resources towards securing reliable hydrological data for planning and operation of hydropower systems.

In order to obtain the level of data required to secure an optimum pay-back of the investments in hydropower construction and operation, the hydropower utilities themselves should, if necessary, subsidise the governmental water resources agencies with funds, transport and equipment for collection and dissemination of relevant hydrological data.

There has been a growing awareness in recent years of the potential impact of global climate change on the hydrological regime. Several countries have initiated research which investigates changes in precipitation and run-off which can effect hydropower production. In some regions run-off may decrease, in others it may increase. It may affect both economy and risks.

3.5 Hydropower Technology

It has not been considered appropriate to include discussion of hydropower technologies here. However a brief summary of recent developments is attached at Annex 1.

4. HYDROPOWER - MANAGEMENT OF THE ENVIRONMENT

4.1 Hydropower and its Environmental Aspects

As the previous Chapter indicates, the development of hydropower must be viewed in the overall context of a policy of sustainable development. In order to achieve this, hydropower must be able to mitigate some of the more important direct physical impacts of hydro-power development. It must also enhance development opportunities connected to the exploitation of the water resource and provide flexible management of the water for the future when possible.

4.2 Environmental Problems

The most important physical and biological impacts associated with the problem side of hydropower development can be summarised as follows:

- Impoundments - loss of land
- Resettlement
- Health problems
- Changes in waterflow/water level regimes
- Changes in water quality and sediment regimes
- Loss of recreational and other economic activities
- Flood risks
- Tectonic effects in exceptional circumstances
- Ecological changes
- Indirect effects

In addition one should keep in mind the total potential environmental impact caused by the ultimate end-user of the electricity produced e.g. aluminium processing plants whether it stems from hydropower or from fossil fuelled plants.

The impact of impoundment and loss of land due to hydro-power development has already been extensively documented. Loss of farming land on many schemes has been highly disruptive and the effects of eutrophication can be very negative. Flooding of impounded land has also given rise to hygiene and health problems. Resettlement of local resident populations has been recognised as a particularly difficult problem for which there seems to be no adequate solution, other than tailoring the scheme to settlement geography. The impacts of changes in water flow and water level are still not fully understood, but they include the numerous problems created by sedimentation, erosion, increasing salinity and saltwater intrusions. These can all have extensive impacts on downstream agriculture and fisheries. In general, negative impacts brought about by changes in flow can be reduced by constructing a project on a tributary rather than on the main channel. The scale may also be reduced from technically feasible levels to environmentally acceptable and socially and politically feasible

levels. In some countries the physical presence of a hydropower scheme has meant a loss of recreational resource and changed transportation patterns. However this effect can perhaps be avoided by careful planning in advance. In some cases where rivers carry a lot of organic material especially where the temperature is high and gradient is small, impoundment or damming can cause oxygen depletion. Fish-kills have been reported only from rivers in the sub-tropics where such conditions occur. Tectonic impacts have been reported only from very large hydro-power schemes where the sheer weight of the water and the dam structure combined with repeated changes in water level can trigger earth tremors. The existence of large dams might impose fear of flooding among downstream populations whether real risks exist or not. However, building of dams and creation of reservoirs combined with careful planning and operation of the runoff through the hydropower plants may reduce the risk of harmful floods. Hydropower also has a number of recognised indirect impacts. These include unintended impacts on local micro-climates, socio-economic changes in local communities and ambient ecological disruptions. These indirect impacts can also be beneficial, especially where hydropower is combined with other water uses in a multi-purpose arrangement (see below).

One of the best documented large-scale hydro-power projects in a developing country is the 200 MW Mtera Dam project in Tanzania whose impacts are described in detail in "Towards Sustainable Development", an account of a Nordic Conference on Environment and Development in 1987. Some of the features registered were the hazards of uncleared vegetation in the area flooded, colonisation by water hyacinths, the resettlement of about 3,000 people, improved fishing, impacts on wildlife, increasing deforestation and impacts on local health. The impacts were very diverse. Some were negative and some were positive, depending upon the viewpoint taken. According to the donors the Mtera Dam, on balance, is a success story. (Ref. 5 Annex 2)

Nonetheless most of the impacts mentioned above will impede the achievement of long-term sustainable development. Generally it is easier to reduce these impacts at the planning and design stage rather than after implementation has taken place. Operational flexibility must be planned for early in the process to enable future management of the project to meet altered premises of economic, social or ecological nature in the future. In many cases there appears to be a correlation between size and negative impact. In order to mitigate or reduce impacts, projects may often be broken down into smaller constituent units where possible. In general it can be said that the impacts outlined above are more intense the larger the project is, so that scale and size is a critical factor in hydro-power's role within a strategy of sustainable development. Examples to the contrary can also be put forward. In most cases it has proved to be wise to concentrate the impact on one single, large plant instead of building many smaller reservoirs and power stations within the one watercourse.

The challenge to the planner working within the context of sustainable development is therefore to balance these impacts against the components of an energy policy i.e. efficiency of energy use, promotion of renewable sources of energy, reduction of greenhouse gas emissions and promotion of local welfare and with due consideration to the local people who are most affected by the project.

4.3 Hydropower within a Multi-purpose Context

According to the World Resources Report for 1990-91, total world river runoff amounts to 40,673 cubic kilometres per year (Ref. 6 Annex 2). Of this, about 9%, or 3,528 cubic kilometres is withdrawn by Man for his purposes. About 63% of this or 2,206 cubic kilometres is withdrawn for irrigation for agriculture. Some 3% or 110 cubic kilometres is taken for domestic and municipal purposes and 760 cubic kilometres or 34% is used for industry. Agriculture, primarily in Asia is therefore the major water user in a global context. Water is also harnessed by Man for a great many other subsidiary purposes including flood control, recreation, fishing and wildlife conservation. It is even harnessed for aesthetic reasons, say the creation of ornamental and artificial lakes.

In very many cases the use of water for hydropower will therefore involve the use of water for other purposes. As water management technologies improve, the multi-purpose function of hydropower projects can also be enhanced. Through the incremental formulation of a project for a number of purposes, the hydropower dam and reservoir costs can be allocated to a number of functions. This will reduce accordingly the capital cost of the hydropower project and simultaneously achieve a better resource utilisation. In some cases it has been shown that development of a multipurpose project was only possible thanks to the revenue from power sales from the hydropower plant.

4.4 Management of the Resource

Because of hydropower's potential impact on the environment and its interplay with other water uses in multi-purpose development, there is a clear need for judicious management of the water resource in any country.

In many countries a situation has already been reached with demand exceeding supply and the development of resultant conflicts.

Access to water is a public right, and because there are often many more small users of water than one would imagine, the rights of large users have to be balanced with those of small ones. The following basic principles seem relevant:

- Balance user interests
- Optimise water use
- Secure general environmental objectives
- Rectify problems from the past

Most countries have attempted to introduce some forms of water management mechanism. These can operate on the basis of one river (through a river authority), on the basis of a water basin or on the basis of the national state. Although plans may be formulated it is not always the case that the planners or the responsible authorities actually possess the de facto jurisdiction to implement plans. Norway has prepared a National Master Plan for Water Resources on which most major water resources management decisions are based. In this Plan every hydropower site not yet developed has been classified according to the cost and the environmental impact the development would cause. Only the least contentious sites have

so far been released by the Parliament. These will be dealt with individually when the owners apply for licences to develop them. This procedure has been possible because of Norway's very homogeneous system of administration and its heavy dependence on hydropower for industry. On the other hand there are many cases of highly effective water management operated on a private basis. The operation of the levada winter irrigation system in Madeira is one case in point, the complex water management system for agricultural irrigation in arid areas of Afghanistan and Iran is another.

Water resource management is becoming increasingly important as water sources are more intensively exploited every year. New sources further afield have to be tapped and drawing from groundwater has to be intensified. This can lead to over-exploitation of the resource with intrusion of salt into reservoirs, settling of sub-soils etc. Even where water is abundant, it is subject to increasing degradation. Over-use of fertilisers is a relatively new phenomenon which is causing river pollution and algal blooms and massive fish deaths at sea. Soil erosion, chemical pollution, irrigation salination, excessive organic loading and excessive extraction are all symptoms of over-exploitation combined with poor water resource management.

Water management policy should clearly define the role of hydro-power within some form of water management plan. It is difficult to exploit national hydro-power potential in a rational and sustainable manner without such a plan. The relative priorities of different water users have to be set against one another. This would favour a partial (step-by-step) approach to the development of hydro-power potential. This enables competing or complementary users of the resource to be taken into account at every stage. This is closely related to the question of scale in hydro-power which is discussed above. Examples of over-investment in large projects in the Third World illustrate the validity of this point. An important reason for considering hydropower projects in the context of wider watershed or hydrological units is that such projects tend to act as settling basins and can have critical impacts on downstream reservoirs. The failure to view comprehensive water resource management as part of the sustainable development process has many examples e.g. the pollution of surface water in Poland, the conflicts between water users in Lake Baikal and the competing claims of hydro-power, domestic and industrial water users on the River Danube.

If the local population are actively involved in the planning and implementation of a hydropower scheme and are allocated a fair benefit, then experience shows they will take a more positive attitude to it. On the other hand if the share of benefits falling on the local population is too generous then the promotion of hydropower will have to be counter-balanced not only from an economic viewpoint but also from an environmental one.

5. ECONOMIC AND FINANCIAL ASPECTS

5.1 Optimisation of Resource Utilisation

Hydropower schemes are characterised by high capital investment requirements and very low follow-on costs for operation and maintenance. The follow-on costs are very stable. The major part of the capital expenditure is incurred for the civil engineering works which have to be built on the particular site of the scheme. The electro-mechanical equipment has to be manufactured centrally; often it is imported.

The preponderance of the civil component and the benign operating conditions give hydropower plants a very long life span, 2 - 4 times longer than for thermal power plant of equivalent size. Where tunnels, underground power-houses, and earthfill dams are involved, these can easily be kept operating for several generations. However inflowing silt in reservoirs may reduce greatly useable storage capacity, reducing thereby the economic life-span of the whole plant. The electro-mechanical equipment can also be kept in service for long periods of time through part-replacement and refurbishment; many parts of this equipment do not suffer a great deal of wear in operation partly because it operates at ambient temperatures, but they may become outdated and ultimately less efficient compared to new equipment.

Economies of scale apply to the development of hydro schemes as they do to other power plants. For that reason, hydro plants should apparently be developed to as large a scale as the resource permits provided a power market of adequate size is available. However social and environmental constraints and demands for other uses of the water impose limits on the scale of the development. Effective and environmentally sensitive planning therefore entails finding a balance between these two principles which comprise a whole host of decision variables which must be recognised.

Water has an inherent value, not only for hydropower but also for other uses. It becomes upgraded in value once it is converted into electricity and, in that energy form, it becomes a competitive alternative in power system planning. In broad terms, hydropower schemes should be so conceived that the net value (environmental costs and benefits included) of their output is maximised for the power system to which this output is supplied. The economic features of hydropower are strengthened by its flexibility of operation, rapid response and the large-scale energy storage which hydro plants permit. Development of hydropower does not necessarily reduce the use of water for other purposes.

The ready commercialisation of hydro energy through the electricity market should not, however, mask the need to develop water resources also for other purposes for which valuation of the output is more difficult. Perspectives between user interests may differ and comparison of the value of uses on purely economic grounds is often difficult. Priority development plans need therefore to be set which override economic consideration and in which hydropower is allocated its role on socio-economic and largely empirical grounds.

In such resource allocation, environmental impact assessment also now plays an important part. The environmental impacts of hydropower are materially different from those of other new and renewable, sources of energy. Some hydro schemes have a negative impact on the environment, principally at a local level and associated with the conception of a particular scheme but nevertheless disturbing. Hydro schemes should clearly be planned to maximise their positive and minimise their negative impact. This must be one of the targets for the future and must figure strongly in the optimisation of the utilisation of water resources. As long as the decision-making process is based on economic merit, environmental impact assessment must enter into the economic equation. The methodology for quantification of these impacts is still in its infancy but will have to be developed if emotive judgements are to be provided. This also applies to socio-economic impacts which are gradually being better understood.

5.2 Comparative Assessment of Merit

Once the need for an additional power supply has been established and a hydro scheme which could provide this supply is identified, it is necessary to show to the decision-makers, and ultimately the financiers, whether this scheme offers the best option. An evaluation of total costs and total benefits has to be carried out and set against those of whatever alternative is available to meet the same demand. It must be understood that, at this stage of the development, it is not a question of whether, but how the demand should be met, bearing in mind local, regional and now also global considerations. The best option for providing a specific supply is that which offers least cost overall. A least cost scheme is one that offers the best return on the capital invested after its advantages and disadvantages have been taken fully into account.

Processes for the comparative assessment of the merit of alternative solutions are now well established in some countries. The initial investment and subsequent operating, maintenance and refurbishment costs are weighed against the benefits which the scheme can achieve throughout its life. The benefits are usually expressed in terms of the savings the scheme can achieve in comparison with the costs of alternative solutions. The rate of return for the scheme is then computed from the cash flow of lifetime costs and lifetime benefits. Appraisal of merit then rests on the relation of the rate of return to the opportunity cost of capital in the particular economy, i.e. the return to be expected from an investment in other sectors of the economy.

A new dimension was introduced into the appraisal process by the realisation that conventional methods of appraisal in terms of direct costs and benefits were no longer adequate to assess the role of hydropower in an era of growing environmental and socio-economic sensitivity and scarcity of investment funds. It is generally held that the assessment should extend over:

- the determination of total costs and benefits covering also such environmental and socio-economic effects as can be quantified. Judgement factors might be introduced where quantification is difficult, for example for the reduction of emissions from fossil-fuelled plants replaced by hydropower or the temporary disturbance caused during the construction of the scheme. Incentives given by way of taxation or promotive rates for

energy derived from non fossil-fuelled plants should also form part of the economic weighting of alternative generation. This includes the Non Fossil Fuel Obligation (NFFO) or Carbon Tax envisaged by the European Economic Community which will undoubtedly be applied in other regions also in due time. The aim must be to present a balanced case for or against hydropower and to avoid emotive judgement, as far as this is possible.

- A warning must be given regarding the way carbon taxes should be applied. If they are added to the price of electricity which the end user pays, they will also hit renewable sources of energy which are converted to electricity and supplied to the same system. Taxes according to the "polluter must pay"-principle should be applied to the specific plant where the pollution takes place.

- The scale of development must be considered. The costs and benefits of one large scale scheme compared to a multitude of smaller scale plants giving in total an output similar to the large scheme may turn out in favour of the larger one. However, concentration of the impact on the environment on one place which is less sensitive may be preferred. The appraisal of alternative solutions should therefore include a comparison of alternative hydro schemes of different capacity always keeping in mind the need to supply a specified demand.

- The appraisal process should ensure that the cost advantage of hydropower extending over 50 - 60 years at least is visualised in comparative project evaluation. This advantage does not appear when using traditional discounting procedures which do little justice to projects which can serve the community in a sustainable way. For real comparison of different energy technologies it is imperative that capital expenditures be discounted by using a "real" rate of return and not to undervalue future benefits or skew investments toward short-term or distorted returns to capital.

- Not only local but also national and global interests should be reconciled. The disposition of benefits and disturbance arising from power generation of any type affects different areas in a different way. Traditionally, consideration has been based on an "upwards" appraisal from local to national impact. It has long been recognized that, whilst most of the benefits of power generation are still local or at best national in character, much of the disturbance is transnational. An assessment must take account of these factors and evaluate the merit of a hydro proposal in a more global context. To have such an assessment reflected in decision-making by investors requires agreement on a mechanism of conversion and an evaluation of the viability of a project where the environmental cost is included. It represents a challenge to the world community to find and agree on such a mechanism. One possible measure is to reach general agreement on the principle of Tradeable Emission Permits.

5.3 Alternatives in Resource Allocation

The availability of water resources is finite but their lifespan will be infinite unless there is major climatic change. The call on water resources for whatever purpose will increase with the rising human population and exploitable resources will become scarcer. Development

policy requires decisions to be taken on

what purposes should have priority in water resource allocation; and

to what extent can water resources be exploited without creating unacceptable environmental impact.

Socio-economic considerations rather than market economics should determine these issues. Water, food and energy are three primary requirements for human life and wellbeing. Whilst, for the present at any rate, there are usually alternatives to hydropower for energy production, there are no serious alternatives to water resources exploitation for water supply and irrigation. These two purposes will therefore increasingly claim priority in water use, hydropower being fitted in where this is feasible and economic. Though socially essential, water supply and irrigation often produce little net revenues so that the benefit which associated hydropower can yield in monetary terms can be used to underwrite the economic merit of multi-purpose development.

Environmental sensitivity to hydropower may be encouraged by the fact that alternative energy sources can be found or stringent energy conservation measures introduced. Such steps may be less convenient and more costly but their impact, in a particular context, may be more acceptable. If there are no alternative solutions and if the output from the water resource is vital for continued human life, environmental considerations will become less critical to the issue. A situation may then develop in which the overriding need for water as such will largely overcome objections to its abstraction and storage. Hydropower does not remove any water from the hydrologic system. If hydropower can be developed as part of such a water supply scheme, it is then likely to become an acceptable way of utilising and benefitting a given multi-purpose development concept. Resource allocation can be optimised in such circumstances.

5.4 Upstream-Downstream Issues

Hydro schemes are usually built more easily and economically upstream, where valleys are narrow and river flows fast, than in flatter terrain downstream. It may create problems if all benefits from hydropower are being retained upstream while deterioration by way of regulated river flow, reduced water quality and lower fertility etc are being passed on downstream across national borders. Enhancement of downstream benefits becomes an important matter for any river development. It is usually settled by international agreement where different countries are involved, but it is sometimes overlooked if the river crosses no national boundaries.

A river basin needs to be viewed and developed as one comprehensive whole; whatever is done along the course of the river will affect the whole riparian population. The power development plan therefore has to keep in mind

the regime of the river flow that has to be ensured through compensation of water and discharge regulation,

- the maintenance of adequate water quality,

- the assurance of a satisfactory silt loading downstream,

- the protection of other downstream uses of the river, for irrigation, navigation, fishing and tourism.

Proper preservation of downstream benefits could lead to a curtailment of upstream power production. This may be the price to pay for compatible development and has to be taken into account in the economic assessment of the hydro scheme.

Downstream parties may also be able to take advantage of whatever favourable supply conditions the hydro scheme can offer. The land upstream is often mountainous, the population density in downstream areas tends to be much larger and the power market also. The scope for hydro there is restricted by the terrain; thermal power provides most of the electricity requirements. Upstream hydropower transmitted to downstream users usually has an economic advantage over thermal generation and, as far as it can replace such generation, it will allow thermal emissions to be reduced. Nevertheless, an adequate incentive has to be offered to the downstream user to make him forego some measure of independence in his electricity supply.

The income from downstream sales must contribute towards the upstream costs, otherwise there may not be an adequate incentive to build the upstream hydro scheme in the first place. The bulk of these costs will be for the initial capital expenditure and if this has been incurred in foreign currency - because the plant was financed by foreign loans - the revenue from bulk sales of electricity must be in convertible currency so that the developer's loan redemption requirements can be met. Thereby lies a dilemma for the purchaser of the power: import of hydropower may cost foreign currency in the same way as fuel purchases for thermal plants. The incentive for buying the hydropower will then be strictly on price alone unless some recompense is made - perhaps from an international fund for reducing his thermal emission - or through the sale of tradeable emission permits. This raises particular problems for developing countries where both the supplier and user are dependent on foreign financing of the power system expansion. Financing agencies will have to consider the position of both supplier and user and, where necessary, facilitate crossborder subsidisation in support of sustainable development.

5.5 Financing

Hydropower is characterised by high initial investment costs and very low expenditure for operation and maintenance. In consequence, the production costs are determined largely by the capital redemption charges and hence by the financing conditions under which the original investment capital was procured.

The financing conditions depend on

- the scale of the development and hence on the capital sums needed and the sources that can be tapped for funding;

- The economic conditions within which the scheme is to operate and hence the risk involved in the enterprise;

- the status of the developer and the financial resources available to him.

Financing scenarios tend to be complex, particularly where the developer has few resources for self financing and has to depend on outside parties to support his scheme. The less developed the economy the greater is the financial support that the developer needs. Support requirements can extend over the whole development process, from initial investigations through design and construction to operation, maintenance and ultimately rehabilitation. The resulting indebtedness of the developer can impose a serious drain on the national economy as a whole.

Although reliance on outside funding sources can lead to some loss of independence in planning and development, the investigations which funding agencies will wish to carry out do at least ensure that the proposed scheme is sound and compatible with national conditions. They ensure also that socio-economic and environmental impacts have been explored to an internationally acceptable standard. On the other hand, much of the decision-making process is transferred to outside parties and this could affect the prospect for small and remote schemes for which the economic case is often not very strong.

Sources of finance fall into the following categories:

- National funding through self-financing and inputs from the national public and private sector;

- Foreign financing on a commercial basis through financing institutions and equipment suppliers, including concessionary finance.

The trend is now increasingly for mixed financing in which different sources are tapped. The financing conditions become more favourable through the admixture of aid and concessionary finance.

Bilateral and multilateral agencies now tend to move away from a project-by-project approach and fit financing plans into a general energy development strategy with a regional rather than national orientation. The future role of hydropower will be greatly strengthened if its strategic importance is fully recognized. Issues such as pollution abatement, environmental impact control and the possibility of associated taxation which is to guide the development process along acceptable paths are likely to cause financing scenarios to be viewed in a new light, particularly if it can be shown that hydro can bring benefits that cannot be achieved from alternative sources. The proper disposition of incentives and disincentives could lead to considerable growth in concessionary financing and open up a new era for hydropower by overcoming some of the burdensome financing problems that this sector currently faces.

Hydropower has the disadvantage of heavy "front end loading" (i.e. capital is tied up for a long time, with very heavy costs initially). For international funding e.g. from Development Banks, this is not such a problem. They already often offer loans with an initial grace period, a long period of repayment, and, perhaps, at concessional interest rates. Commercial banks,

however, follow the market - which works to the disadvantage of projects which have heavy "front loading". There are various ways in which national governments could intervene so as to assist in the financing of projects which would otherwise be unattractive to commercial banks. Alternative sources of international finance (notably the Global Environment Facility) may be called upon.

Regarding hydropower development in developing countries the following views were brought forward:

Most of the remaining unexploited hydropower projects are found in the developing countries. These are also where the increase in the energy demand will be greatest because these countries are so far behind in their per capita consumption as compared with the industrialized countries.

Conservation of energy is of greatest consequence where there is a high consumption, i.e. in the industrialized countries, but the promotion of an energy efficient economy is important also in developing countries.

The developing countries naturally do feel that it must be their right to make use of the cheapest energy sources to meet their increase in demand, even through technologies which will add to global pollution and global warming.

If the international community, due to environmental concerns, wants to restrict the use of cheap fossil energy in the developing countries, then it should be ready to cover the cost difference, i.e. pay the "carbon tax" required.

One answer to the pollution problem is to use renewable sources of energy as for instance hydropower. Where it is more costly to construct hydropower plants the industrialized countries who have been harvesting their cheap, but polluting energy resources for generations, should carry the extra financial burden which is placed on developing countries if they shall meet their future energy needs with more expensive hydropower development.

One way for the rich countries to help carrying this burden would be by making available long term credit which postpones the servicing of the debts long enough to make it possible for poor, but hydropower rich countries to pay back at a slower pace and to pay more towards the end than in the beginning.

If hydropower projects in developing countries are made more expensive because donor countries or agencies impose their own rigorous environmental standards on them as a precondition for assistance, then these countries or agencies should bear the extra cost involved.

If rural electrification in developing countries is introduced as a means of erosion control through reduced rate of deforestation, then the price of electricity must be brought down by outside subsidy sufficient to make electricity affordable for the rural people.

6. INTERNATIONAL AND REGIONAL CO-OPERATION

6.1 Alternative Arrangements

National boundaries often separate important hydro resources from electricity markets. Hydropower development then involves the linkage of resources and markets in an international context. The principal arrangements cover

- the exploitation of imbalances between resources and demand through
  - tied schemes located in one country and supplying bulk power to a neighbour on a long-term contractual basis;
  - power exchanges between neighbours to take advantage of complementary situations arising from differences in seasonal conditions, time activity or micro-climate;
  - supplies from hydro to thermal power systems to achieve reduction of thermal generation, and of consequent emissions, at times of adequate water availability.
- the development of large resources which may be desirable to achieve economies of scale but for which there may not be an adequate market inland; this includes also the production of by-product electricity from multi-purpose use of water, in particular in connection with water supply and irrigation.
- the bilateral utilisation of hydro schemes sited on main rivers which form national boundaries or pass from one country to another.
- the alternate installation of larger plants in neighbouring countries to take fuller advantage of the available resources capacity, avoid duplication and reduce investment requirements.

Successful development demands in all these cases that there should be close cooperation between the countries involved so that maximum advantage can be derived from the exploitation of a given resource. This is particularly important in situations where the major power potential is located upstream but the primary power markets are downstream. The requirements of downstream countries may extend to other uses of water, more specifically to an adequate, regulated and seasonally adjusted water flow.

6.2 Planning, Development and Exploitation

The sharing of facilities that can be contemplated depends on the characteristics of the power source and the power demand. These characteristics have to be explored and cooperation initiated in the planning stages of a hydro scheme. The influence of watercourses on the socio-economic situation and the energy balance usually extends to a regional scale and

requires assessment in a regional context. This is particularly so for larger river basins where exploitation can affect a number of countries, but it need not be limited to such cases.

Complementary situations which could lead to savings in energy production and also in investment funds exist in many regions. Some have been exploited, in particular in Europe and North and South America as well as bilaterally in South-East Asia and in Africa. Others are under study in Central America and the SADCC Region of Africa. There is considerable scope for close regional cooperation for which, in virtually all cases, hydropower forms the focal element. This has been recognized by many international financing agencies and these now require every development proposal for larger hydro schemes to be examined in a regional context. A rather extreme example of this is the potential hydropower site on the lower reaches of the Zaire River which could be developed up to a capacity of 40,000 MW as run-of-the-river plants with virtually no dams involved. It could clearly serve a large area covering several countries with non-polluting energy.

Some countries still wish to be self-sufficient in their energy supply and are wary of undue dependence on others. They will dimension the size and phasing of their hydro schemes strictly to their inland demand. Nevertheless, they are usually dependent on imports of fuels, goods and services and also on foreign support for financing their power system expansion. These two situations are difficult to reconcile. Development agencies now universally review requests for technical and financial support in the light of the international implications of the proposal. They agree that undue autocracy leads to wastage of resources.

6.3 Regionalisation of Development Policy

This matter can be considered under two headings:

1. for cases where river courses are not shared and where complementarity relies on differences in the energy supply potential and the power demand.

2. for cases where river courses are shared, either jointly or consecutively, and where there is therefore a common interest in the exploitation.

Both cases offer scope for the substitution of hydropower for thermal generation. In the first case, cooperation will be restricted to the energy sector and lead to a unidirectional supply or reciprocal exchange of power, sometimes time-restricted although the advantages of regional cooperation usually encourage permanent arrangements. Hydropower surpluses, seasonal or permanent, and the ready availability and flexibility of hydro plants as well as the large-scale storage of energy which they make possible, form the basis for cooperative development.

The sharing of river courses offers considerable scope for regional cooperation, be it for sharing of riparian benefits or the disposition of benefits between upstream developers and downstream users. Upstream conditions are often more suitable for hydro development and can bring ready advantages to the developer by way of reduced deforestation and pollution and the availability of cheap electricity, but this may be at the expense of some environmental disturbance. The downstream user will also benefit from reduced pollution if

surpluses of upstream power are supplied to him.

Careful water management will also improve river training and offer a water supply for other purposes. Benefits from all uses need to be shared equitably between the two parties and the development policy of both shaped accordingly.

It is important that developing countries should play a leading role in the formulation of development policy affecting their region and steer it so that it is compatible with local circumstances. They should help to ensure that legislative measures deal with the river basin as a whole so that optimum use of resources can be achieved.

6.4 Financing Issues in Regionalisation

Whoever develops a hydro resource will be faced with a substantial financing problem. If the benefits are to be shared with others, it is essential that the developer receives adequate recompense from the supply of electricity to other parties so that his financial burden is eased. There are basically two ways in which this is done

1. With power exchanges, supplies can be valued in terms of the quality and quantity of the energy supplied and a balance of export and import values established for a given period. Accounts are then settled in terms of energy and no money changes hands, as was the case in some European exchanges.

2. With unidirectional supplies and unbalanced exchanges, mutually agreed bulk supply rates are applied to the quantities exported.

Chargeable bulk supplies provided from power plants built with the aid of foreign grants or loans generally require payment in convertible currency to ease the loan redemption commitments of the developer. This question was further discussed under 5.4.

7. HYDROPOWER IN AN INSTITUTIONAL CONTEXT

7.1 Institutional Problems

This Chapter discusses the issue of developing appropriate institutional and legal frameworks within which hydropower can operate in a sustainable manner. If the proper institutional framework does not exist then the project being implemented will not be sustainable.

It is, of course, very difficult to generalise on such matters because of the diversity of existing institutional, legal and administrative systems which govern the operation of hydropower in different countries.

Two main issues seem to have emerged in recent years. In developed countries a common problem appears to be that hydropower development is often still operating within institutional structures which have been developed 60 to 80 years ago. In many instances these have little or no relevance to-day. There is therefore a need to restructure institutions so that they more accurately reflect the aspirations of to-day's society. In developing countries, on the other hand, a common experience has been that inappropriate institutions have been developed and often large international organisations have little understanding of the needs of developing countries. In particular institutional structures imported from overseas have difficulties in meeting the needs of smaller projects. In Nepal, for example, there are several networks of small, dispersed projects. Appropriate local institutions are required to handle these, and conventional, centralised organisations often find it difficult to adapt to such local conditions.

In developing countries in particular there is therefore a need to undertake institutional development in front of or in parallel with project development rather than afterwards, if this in fact is possible. It has to be recognised, however, that management structures in most countries have evolved in response to immediate needs rather than deliberate long-term planning.

Considerable concern has been expressed over the problems arising from the differing institutional needs of developed countries and developing countries, of urban and rural communities and of large and small-scale hydropower projects. In particular there is concern that appropriate institutions should be established to meet the needs of rural communities which are often served by small-scale schemes. Transplanted institutions, conceived in other countries, and developed for large-scale urbanised/industrialised communities are not appropriate in rural communities. This indicates that different institutional networks might have to be developed for large-scale and small-scale hydropower projects. In fact several developing countries have developed their own specific institutions for the planning and implementation of rural electrification, e.g. the use of rural electric co-operatives in the Philippines.

Nonetheless, although appropriate institutional organisations are desirable for different scales of project, there is no avoiding the need for a central, national entity to deal with major

issues which can affect even the smallest project. A national agency, for example, is required to integrate the smallest project into a national system of power (and water resource) development. Similarly a national institution will be necessary to set and enforce uniform design and operation standards on a national or international basis.

When operating at different scales it is important that the choice of institution for hydropower development and operation takes account of existing county, municipal and local government structures. It may well be possible to use existing structures rather than developing something new and untried.

7.2 A Generalised Model

Despite the difficulty of generalisation several generalised models for institutional development within the hydropower sector have been promulgated.

There would appear to be an initial institutional paradox. While it is argued that a sustainable energy policy should encourage the fostering of local participation and the creation of local livelihoods, there can be no avoiding participation by a central organisation in hydropower development. This is because of the nature of hydropower technology which is relatively capital intensive with a need for inputs of foreign capital/equipment.

It has been usual for the institutional framework for electric power to be of a dual nature. Central government, the regulatory body has been responsible for national energy policy, national energy planning, environmental policy, financing, legislation and legal rights, licensing and public safety regulations. Experience in most countries suggest that these issues should be co-ordinated by one Ministry. The power utilities (which may be either public, private or parastatal) are the executive body. These are responsible for the planning, construction and operation of power systems, plants and transmission grids. Such utilities require to comply with policies, licences, regulations and laws issued by Government.

Such a model requires that the required functions of each body are in place and operate normally, and that a sufficient number of qualified staff and professionals is available. Experience from many countries also suggests that where there is a Government monopoly in the power sector, there is a frequent danger of political interference. In most developed countries the institutional framework is well developed and functions effectively. However in developing countries the picture is more diffuse.

Problems most frequently arise in very large schemes in relation to the existing power system and in very small schemes in rural areas. Large new schemes put a heavy demand on existing institutional resources, and in many cases a special organisation may have to be created to handle the scheme. This can have many pitfalls. Rural schemes, on the other hand, are often so small that they are of marginal concern in institutional development. Electricity utilities are experienced in supplying large urban conglomerations, but much less so in dealing with isolated rural areas. Small-scale programmes can be brought into focus by creating organisations with a separate identity. Because of the nature of rural electrification schemes in Nepal for instance it has been necessary to make special institutional arrangements for groups of isolated rural networks. In most countries local electricity organisations prefer to

maintain links with a central utility because of foreign currency and other external issues which can impinge on rural electrification.

7.3 The Legal Framework

Because it is a technology which utilises natural, renewable resources, hydropower needs a proper legal setting within which to operate. In order to implement projects in an effective manner, there have to be legal powers to acquire and if necessary expropriate ownership rights to rivers and to land. There has therefore to be adequate legislation to govern the licensing of hydropower development. It is thus essential that a legal system be developed which can resolve conflicts between different users in a rapid, but safe and effective manner. There has to be legislation to regulate the use of electricity as it can be a hazardous technology if not properly controlled. There is also a need to develop legislation to supervise and co-ordinate the development of an electricity supply system. Development plans for the hydro-power sector require an adequate legal framework.

Many countries suffer from defective legislation covering the hydropower and electricity sectors, and many suffer from out-dated and inappropriate legislation derived from other cultures. Where possible legislation governing electricity development and water resources development should be combined.

Experience indicates that where legislation is defective or non-existent it is always preferable to start constructing a more adequate system even although it may not be appropriate. This is because lack of legislation can be a direct impediment to development. The legal system which is developed should ensure that powers of decision are not fragmented. A Ministry or Directorate with sufficient authority is a necessary pre-requisite for the building up of a proper legal framework.

The overall concern is that legal and institutional frameworks exists to assure that decisions can be made and that those decisions be implemented.

It is imperative that one entity be charged with the responsibility of bringing the process to a point of decision - doing so with balance of conflicting demands.

With this overall direction the decisions should be "forced" to the lowest or smallest practicable level.

8. ESTABLISHING KNOW-HOW - TRAINING AND TECHNOLOGY TRANSFER

8.1 Personnel Development

Training and development of technological knowledge are closely interlinked with international cooperation. Hydropower development has spread from the industrialised to the developing world and it is essential that this should be accompanied by an appropriate flow of technology. The aim must be that the developing countries build up their capacity so that they can participate actively in the development process. This is to ensure that new projects planned for and built in these countries are fully appropriate to local conditions and compatible with the environment into which they are introduced. Local personnel must not only be able to guide this process, but they must be able to operate and maintain the facilities effectively and ultimately to rehabilitate them so that they can fulfill their proper function throughout their asset life. It is clear that, unless this is achieved, the benefits expected from the development will not be realised; investment funds will have been partially wasted and socio-economic progress of the local population retarded.

Hydropower should not be viewed in isolation. Virtually all technical training can have some relevance to the hydropower sector. Moreover, the sector covers only one aspect of water resources exploitation in general. Formation of personnel for the hydropower sector should bear in mind the importance of proper utilisation and management of water resources and the interlinkages between different uses which must be fostered in the interest of future generations. There is danger in training being focused too narrowly and the overall view being lost.

The importance of an adequate human resource development (HRD) effort for building up an effective local capacity has been widely recognized. It is now common practice for development agencies to include job assessment, training and manpower performance components in every project to be studied and developed. Full participation of local personnel in all activities is usually called for, supplemented by the transfer of computer programmes and a comprehensive information portfolio. The aim is to develop know-how through on-the-job training and to ensure full familiarisation with the project. This process has not always been as effective as may have been hoped. Organisations entrusted with this work are often under severe financial and time constraint and this can seriously restrict the HRD effort. Personnel development needs to be accorded priority in the ranking of development work and pursued as an activity in its own right.

Outside agencies should not come with ready made plans which are dictated to the local recipient with the authority of the donor. Plans must be prepared and problems solved together with the local counterpart.

Feasibility studies and design should be carried out in the country where the hydro development is to take place. This action must involve to a larger degree local engineers and engineering firms at all stages of the development. All projects must include a training or technology transfer component which is of fundamental importance. Sustainability implies

the ability of the local personnel to carry on after the consultants have left the plant in local hands.

The principal options available for personnel development include:

- direct involvement in responsible positions within implementation schemes
- training in foreign countries through secondment of individuals with utilities, academic institutions, manufacturers and consultants, including vocational training for technicians
- group training in foreign countries through standard or specially arranged courses
- in-country training of individuals or groups by expatriate personnel at established or appropriately strengthened institutions
- on-the-job training for all grades of personnel
- training through participation in seminars and workshops covering all aspects of the hydropower sector.

It is sometimes difficult to ensure that personnel is retained on the work for which it has been trained. The position is made more serious in developing countries by the small pool of suitable personnel that may be available. Governments and utilities have to face up to this danger and offer suitable incentives to avoid such drift. To develop and conserve a nucleus of people competent in hydropower technology it is important to take a long term view and try to maintain a relatively stable and continuous activity related to hydropower development.

8.2 Sharing of Experience

The differences in the application of technology are far greater between countries usually classified as 'developing' than they are between the industrialised countries. This is particularly so in the hydropower sector where a number of developing countries have made considerable strides. However, there is much scope for the sharing of experience within the developing world; such experience is often more appropriate in view of regional similarities of ambient conditions in the widest sense.

Sharing of experience can be achieved by opening up in-country training institutions to participants from elsewhere in the region or indeed by group training of candidates drawn from all parts of the worldshore. An example of in country training is the course for Nepalese hydropower engineers at the University of Rorkee in India and the courses in hydropower and electricity supply provided by NORAD for graduate engineers from developing countries at the University of Trondheim in Norway.

Closer regional cooperation in the hydropower sector is leading to the formation of special training centres specialising in this technology, as for example at the Regional Training Centre for South-East Asia in Hangzhou, China.

Greater regionalisation of development has led to the establishment of regional networks designed specifically for the sharing of experience. The first network set up with the support of the United Nations is centred on Hangzhou and now embraces 14 countries in the South-East Asian and Pacific Region. The objective is to promote and support hydropower development through wide-ranging exchange of information and active discussion as well as visits to and critique of specific installations. Through regional cooperation in Africa between the SADCC countries a training centre has been set up at the Kafue Gorge hydropower plant in Zambia. Collaboration in Latin America is likely to lead to the setting-up of further networks and considerable strengthening of local capacity for leading and participating in future hydropower development.

8.3 Participation in Construction and Manufacture

Hydro plants are characterised by a large civil engineering component besides the electro-mechanical equipment. This offer much scope for developing countries to participate in their construction. Such participation not only reduces import requirements but encourages industrial development in general.

Construction materials are now generally procured from local sources. Local participation in the construction effort is also quite frequent, especially for the appurtenant works such as access roads, site clearing and excavating and general building. More advanced countries assign virtually the whole construction work to local contractors.

Much of the fabrication work of say gates and conduits can also generally be assigned to local firms but only a few countries can manufacture the motive machinery. In some, China and India for example, the local market is large enough to absorb a wide range of manufactured machines and a fairly advanced industry has developed which even supplies the export market. Some others, such as Nepal, can make relatively complex but robust small machines particularly suited to local conditions.

With the decline of hydropower development in most of the industrialised countries, firms manufacturing hydro plant have tended to combine into very large international groups with manufacturing facilities in many countries. Sources of quite complex equipment are therefore relatively accessible to developing countries and this can help to bring about technical and manufacturing support and foster cooperation. It can also ease the financing burden.

Countries with relatively small hydro resources would be unwise to develop a manufacturing capacity for more complex hydro components because their market is likely to be restricted and international competition in the world market is intense. There may be scope, however, for the establishment of regional manufacturing centres backed by existing trade arrangements, for example in the Asian Region. The manufacture of equipment which can also be used in water supply and irrigation may offer further opportunities.

Attention should be given not only to the initial manufacture of component parts but also to their maintenance and refurbishment. Properly equipped workshops staffed with experienced personnel form an important element in the operation of a hydro system. Even relatively small plants will require workshop facilities for component repair and replacement; such

facilities may be centralised to deal with several plants. Regional workshops may be set up to cope with major items of equipment. Workshops will also offer scope for the acquisition and formation of skills which will be invaluable for industrialisation at large.

8.4 Realisation of Long-Term Benefits

Implementation of the measures previously described will permit countries to play an essential part in the exploitation of their own resources and will also enable them to offer support to others in their region. Skills acquired in any sector of water resources management can often make a valuable contribution to development in other fields so that even in countries with restricted scope for hydropower the fruits of training and technology need not be lost.

Where development scenarios focus on small-scale schemes for remote and rural areas and where experience in their conception and operation has not yet been gained to an adequate extent, much can be gained from the installation of local demonstration plants. These may be particular small units for meeting a local demand which are designed and built specifically for maximum local participation, not only during their planning and construction but also throughout their operating life. The plants can be used for operator training and upgrading of labour; the experience gained by the personnel can be beneficially applied elsewhere, and not necessarily in the hydro sector only.

The local population in remote and rural areas is often unaware of the potentialities of an electricity supply if it is introduced for the first time. The population has to be educated in the use that can be made of electricity. Such user training can not only make the supply arrangements more effective, but it can also help with the general education of the local people.

ANNEX 1

RECENT TRENDS IN HYDROPOWER TECHNOLOGY

Introduction

1. Dams
2. Power house
3. Rock Engineering
4. Desilting
5. Standardization of small scale hydropower plants
6. Automation
7. Landscaping
8. Construction Equipment
9. Hydropower technology in industrial versus developing countries

Introduction

Hydropower represents a mature technology which has developed and been refined throughout this century. It is well documented in books and articles. Therefore we see no need to explain this technology in general. However, it may interest some readers of the report to understand recent trends in some parts of hydropower technology, e.g. dams, rock engineering, construction equipment etc. The general trend is in favour of reducing costs and in adapting the design to the environment. Its focus will primarily be on conditions in industrialized countries. A critical appraisal is required for application of some of these technologies in developing countries.

1. Dams

There are basically two main types of dams; i.e. concrete dams and embankment dams.

Since the Second World War embankment dams have become more economic mainly due to the development of construction equipment. A watertight zone has to be constructed, either on the upstream face of the dam or centrally within the core of the dam.

Recently bituminous materials, so-called asphaltic concrete, have been used for impermeable membranes in embankment dams. Such dams are being built up to 300 metres high. Former problems of settlements of the embankment have been overcome.

Roller compacted concrete (RCC) has been developed as a new technique and is being used for building new dams and for improving older ones.

Weir constructions made of a rubber hose filled with compressed air are being introduced as a low cost simple design.

2. Power Houses

Due to expanding power markets and integrated power systems increasingly large generating sets can be absorbed without causing too much trouble during drop-out failures.

Where there is a scarcity of space or where real estate prices are high switchyard components of the so-called SF6 (Hexasulphurflour) gas insulated type are more frequently used. This gas is inert and non-toxic, but requires careful handling. It gives possibilities for environmentally friendly design of switching stations in densely populated areas and of highvoltage electrical installations underground, e.g. in underground hydropower stations.

3. Rock Engineering

Experience in Norway and elsewhere show that, when dealing with hydropower projects based on natural heads, power houses and waterways leading the water to and from the turbines can more economically be placed underground than overground. Underground designs give environmentally friendly solutions. The water can be conducted in tunnels through mountains which give flexibility in localization of reservoirs, e.g. in neighbour water courses where the flooding caused by artificial reservoirs may be less damaging to the environment.

Modern full-profile drilling equipment represents a relatively new construction technology which gives opportunities for even further improvements. It renders concrete lining of tunnels unnecessary. (In Norway, the rock quality normally permits blast tunnels without concrete lining, but with additional cross-sectional area, which gives reduced costs).

4. Desilting

Silting up of reservoirs reduces the economic life span of reservoirs if the water comes from heavy silt carrying rivers. Careful design and operation of silt removing devices is necessary. New methods are being developed which reduce such problems.

5. Standardization of small scale hydropower plants

Hydropower also shows economies of scale. The cost per kWh from small plants is generally higher than from larger plants. Such higher cost may under certain circumstances be compensated by lower cost of distributing the power to the consumer. Still much effort has been expended in bringing costs down by simplifying the design of small scale plants. Not very much can be achieved on the civil works component, but the cost of electromechanical equipment can be brought down by standardization of design. Up to about 1 000 kW sets can be delivered and installed ready-made by selecting from manufacturers catalogues of standard sizes. Standard design can also be used up to 5 000 or even 10 000 kW, but in this range "tailoring" to the site becomes gradually more important.

Standardized design facilitates installation of small scale hydropower plants in irrigation canals and water supply systems where pressure drops are provided by concentrated structures.

Standardized design and equipment generally lead to compact plants and therefore reduced impacts on the environment.

6. Automation

As the cost of manpower has increased in industrialised countries automation of the operation of energy supply plants has been gradually more common. Modern hydropower plants are often fully automatic operated with no continuous surveillance except through data equipment and from remote control centres. This brings operation costs down and improves working conditions for the remaining operating personnel.

Excessive automation may introduce a risk of operation failure. However, it should be measured against the risk of failure through faulty operation caused by non-qualified personnel.

7. Landscaping

Environmental impacts and degradation caused by hydropower development in the past should not be used as a reference for new developments. With growing public awareness of the value of conserving and maintaining the balance of nature much has been improved and much has been achieved in adapting hydropower technology to recent trends. By careful design of the landscape when impacting it with large structures or comprehensive modifications of the natural environment much of the damage can be reduced. Although, generally speaking hydropower does damage to the environment, it should also be mentioned that by careful planning and landscaping it may turn out to be of interest to the public in the form of outdoor recreation sites and sites for visits from schools and by tourists. Landscaping has become an important part of hydropower planning.

8. Construction Equipment

Civil structures and civil works of typical hydropower plants usually represent around 50% or even more of the total costs. Much of this work is moving large earth and/or rock masses. Where the topography is rocky or the power house is placed underground rock drilling and excavating of rock masses become a heavy cost component.

To counterbalance rising costs of manpower in the industrialized countries construction equipment for civil works has been steadily improved to handle rock drilling, excavations and transport of masses. To achieve the economies of scale this has led to larger dams, larger and longer tunnels and larger power houses.

In countries where the cost of manpower is cheaper or the import of costly construction machinery puts strain on the balance of payments such heavily mechanised construction methods should not necessarily be adopted.

9. Hydropower technology in industrial versus developing countries

The present trend in hydropower technology is, of course, a result of the experience gained and the need faced in the developed countries. Most of the hydropower potential remains in the developing countries. For development of hydropower in these countries, there is a need to adapt the technology to the prevailing conditions there, i.e. availability of cheap manpower, most of the construction material and equipment and electro-mechanical and control equipment have to be imported while the balance of payment represents a constant strain on their economy.

This requires a different way of calculating the best solution regarding use of manpower and imported equipment and services. Construction methods and solutions which are best in developed countries may not be the most appropriate in developing countries.

Standardised equipment and design should also be adopted in developing countries to benefit from lower world market prices; or to be competitive on the world market if manufacturing is started in the developing country.

Automation and remote control may be of interest also where manpower is cheap if there is a lack of qualified personnel to operate equipment and plants. The optimum solution may be a combination of simple design and qualified personnel, but this is not always easy to achieve.

ANNEX 2

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Hydropower has been developed during this whole century and a vast amount of literature has been produced on this subject. We see no need to present a reference list of such articles and books here. It is readily available from the market and from libraries.

Several international organizations ,- governmental as well as non-governmental-, also deal with hydropower technologies and the potential of exploitable waterfall sites. Further information may be obtained from such sources.